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Performance of Best Relay Selection Between AF and DF Methods in 5G Beyond Perspective

Nurul Hidayati[1], Mochammad Taufik[2], Hudiono[3], Yani Ratnawati[4]

[1] Telecommunication Engineering Study Program,
Department of Electrical Engineering, State Polytechnic of Malang, Malang City, 65141, Indonesia
[2,3,4] Digital Telecommunication Network Study Program,
Department of Electrical Engineering, State Polytechnic of Malang, Malang City, 65141, Indonesia

[1]nurulhid8@polinema.ac.id, [2]moch.taufik@polinema.ac.id, [3]hudiono@polinema.ac.id,
[4]yani.ratnawati@polinema.ac.id

***Abstract*— In wireless cooperative communication, relay selection plays a crucial role in enhancing system performance by improving signal reliability and coverage. This paper presents a comparative analysis of two popular relay selection protocols—Decode-and-Forward (DF) and Amplify-and-Forward (AF)—within the context of best relay selection in wireless communication systems. We investigate the performance of both protocols in terms of Bit Error Rate (BER) across varying Signal-to-Noise Ratios (SNRs). The simulation results demonstrate that both DF and AF exhibit a decrease in BER as SNR increases, with DF consistently outperforming AF at moderate to high SNR values due to its ability to decode and re-encode the signal, effectively mitigating noise. At low SNRs, the performance of both protocols is comparable, as noise dominates the system's behavior. Furthermore, the analysis highlights the impact of dynamic relay selection in optimizing system performance by choosing the best relay based on the current channel conditions. The study also discusses the trade-offs between DF and AF in terms of complexity, computational demands, and overall performance. The findings offer valuable insights into designing adaptive and efficient relay selection schemes for 5G and beyond wireless networks, where both high reliability and energy efficiency are paramount.**

***Keywords*— Bit Error Rate, Relay Selection, Signal to Noise Ratio, Throughput, Wireless Communication.**

I. INTRODUCTION

Cooperative communication has emerged as a promising technique to improve the reliability and capacity of wireless networks. It leverages multiple nodes, referred to as relays, to aid in the transmission of information between the source and destination. Among the various relay protocols, Decode-and-Forward (DF) and Amplify-and-Forward (AF) have gained significant attention due to their simplicity and effectiveness in different scenarios. The choice between these two protocols significantly impacts system performance, particularly in terms of bit error rate (BER), spectral efficiency, and energy consumption.

Decode-and-Forward (DF) relays operate by decoding the received signal, re-encoding it, and then transmitting it to the destination. This approach mitigates noise propagation and is particularly beneficial in high-noise environments. However, DF introduces additional processing delays and may require higher computational resources at the relay node [1]. In contrast, Amplify-and-Forward (AF) relays amplify the received signal, including noise, and forward it to the destination. While AF is computationally simpler and offers reduced latency, its performance may degrade in scenarios with high noise levels due to the amplified noise [2].

Relay selection is a critical factor in cooperative networks as it determines which relay(s) should participate in the transmission to optimize system performance. Best relay selection algorithms often aim to minimize BER or maximize capacity by leveraging channel state information (CSI) between the source, relay, and destination. Comparative studies between DF and AF under relay selection highlight their trade-offs. DF generally achieves better BER performance, especially under high SNR conditions, while AF may be advantageous in low-complexity systems or when CSI is limited [3].

Recent advancements have also explored hybrid relay protocols and the integration of network coding to further enhance performance. These approaches combine the strengths of DF and AF or introduce novel encoding schemes to improve throughput and robustness against errors. This paper delves into the comparative analysis of DF and AF protocols under relay selection, evaluating their performance in terms of BER over additive white Gaussian noise (AWGN) channels. The study provides insights into the conditions under which each protocol excels, guiding the design of efficient cooperative communication systems.

II. METHOD

A. System Overview

The simulation framework is designed to evaluate and compare the performance of Decode-and-Forward (DF) and Amplify-and-Forward (AF) protocols in relay selection scenarios. The system under consideration comprises a source (S), a set of relays (R), and a destination (D), all operating over additive white Gaussian noise (AWGN) channels. The primary goal is to assess the bit error rate (BER) performance of DF and AF under best relay selection strategies while accounting for various channel conditions and transmission scenarios.

The network topology consists of:

1. Source (S): The node transmitting data to the destination, either directly or via one or more relays.
2. Relays (R): A set of N. N relays assist the source by forwarding the transmitted signal. The relays operate in either DF or AF mode based on the chosen protocol.
3. Destination (D): The node receiving the transmitted signal,

either directly or through selected relays.

The relays are assumed to have perfect channel state information (CSI) for both source-to-relay (S-R) and relay-to-destination (R-D) links. All links experience independent AWGN, and the system operates without power allocation to simplify analysis. The block diagram system is shown in Fig 2.

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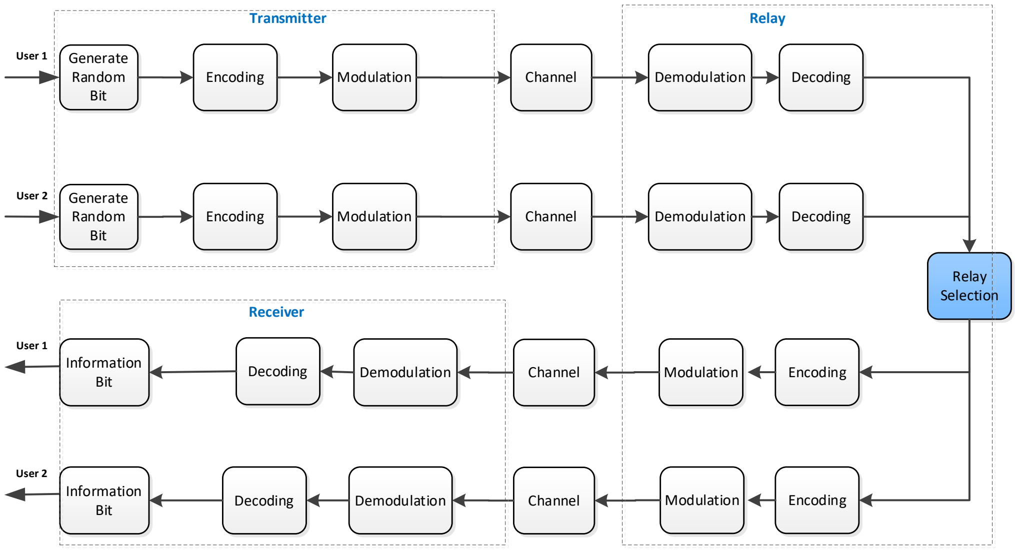

Figure 1. Diagram Block of System

Based on the Fig. 1, it appears to outline a simulation procedure for a communication system using relays and relay selection.

The process begins at the transmitter, which generates the signal to be transmitted to the destination via the relay(s):

1. Generate Random Bits: A sequence of random binary bits is generated to represent the information to be transmitted. These bits are the input data for the communication system.
2. Encoding: The random bits are encoded using an error-correcting code (e.g., convolutional coding, block coding) to improve reliability and reduce the impact of channel noise.
3. Modulation: The encoded bits are modulated into analog waveforms using a BPSK modulation scheme prepare them for transmission over the channel.
4. Transmission to Channel: The modulated signal is transmitted over the channel, where it is affected by noise and possibly other impairments (e.g., fading).

The relay node(s) receive the transmitted signal, process it, and forward it to the destination:

1. Demodulation (Relay): The signal received by the relay is demodulated to retrieve the transmitted encoded bits.
2. Decoding: The demodulated bits are decoded using the same error-correcting code applied at the transmitter, reconstructing the original information bits.
3. Relay Selection: If multiple relay nodes are available, a relay selection algorithm is used to determine the best relay based on specific criteria (e.g., SNR, channel gain, or BER). This step ensures that only the most reliable relay forwards the signal.
4. Encoding and Modulation (Relay): The selected relay re-encodes the decoded bits and modulates them for transmission to the destination.

At the receiver, the forwarded signal from the selected relay is processed to recover the original information bits:

1. Demodulation (Receiver): The received signal is demodulated to retrieve the encoded bits.
2. Decoding: The demodulated bits are decoded using the error-correcting code to reconstruct the original transmitted data.
3. Information Bit Recovery: The decoded bits are compared with the originally transmitted bits (from the transmitter) to evaluate the performance of the system, typically in terms of Bit Error Rate (BER).

The diagram seems to suggest multiple users in the system, where the procedure applies independently for each user. The channel adds noise to the transmitted signal, which introduces errors during transmission. This is modeled as Additive White Gaussian Noise (AWGN) or other impairments. This block is critical for choosing the best relay, ensuring optimal system performance by minimizing errors or maximizing SNR. The BER performance of the system is calculated for different modulation schemes, protocols (e.g., Decode-and-Forward or Amplify-and-Forward), and relay selection strategies. The results help compare the system's reliability under various conditions, providing insights into how the system performs in terms of error rates and signal quality.

The system employs a best relay selection strategy, where the relay with the best channel conditions (e.g., highest SNR or minimum BER) is selected to participate in the transmission. This ensures that the system leverages the most reliable link, optimizing the overall performance for both DF and AF.

This simulation framework provides a comprehensive understanding of the performance of DF and AF in relay-assisted

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communication systems, offering insights into their suitability for different applications and channel conditions.

III. RESULTS AND DISCUSSION

The simulation involves the optimal relay selection through the utilization of single relay selection between DF and AF protocol, as shown in Fig. 2.

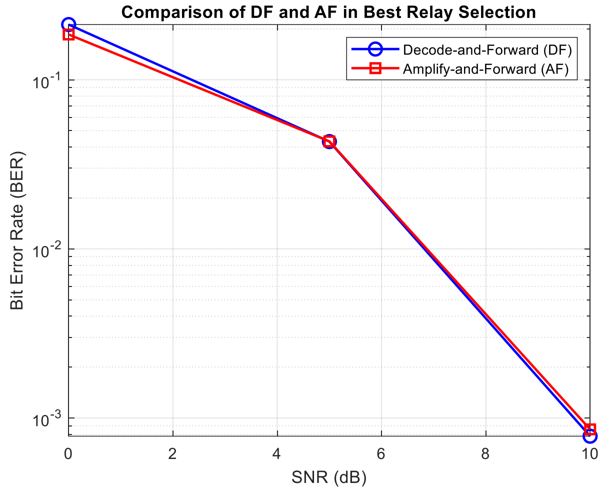

Figure 2. Comparison AF and DF Protocol

The Fig 2 depicts BER versus SNR for AF and DF methods, demonstrating how the performance evolves with increasing SNR. Both AF and DF exhibit a sharp decline in BER as the SNR increases, indicating improved reliability and reduced error rates at higher signal qualities. At low SNR (0–4 dB), the BER for both protocols is relatively high, but the gap between the two methods is negligible.

In the low-SNR region, the BER curves for both AF and DF overlap significantly. This is because noise dominates in this region, making it difficult for either protocol to gain a distinct advantage.

As SNR increases, the DF protocol starts to marginally outperform AF. The DF protocol's ability to decode and re-encode the signal ensures that the destination receives a cleaner signal with reduced noise propagation.

At high SNR, the BER for both AF and DF converges to very low values (on the order of 10^{-3}). In this regime, the channel conditions are favorable, and both protocols perform near-optimally, minimizing error rates

The "best relay" is selected dynamically based on channel conditions (e.g., highest SNR or minimum BER). Relay selection significantly boosts system performance by ensuring that only the optimal relay participates in forwarding the signal.

IV. CONCLUSION

The implementation of a best relay selection scheme significantly enhances the performance of both DF and AF methods by dynamically adapting to the channel conditions. Relay selection ensures that the relay with the strongest channel is utilized, optimizing BER and maintaining reliable communication. While DF provides better BER performance, it comes at the cost of higher computational complexity and delay due to the decoding and re-encoding process. AF, on the other hand, is computationally efficient and faster but suffers from noise amplification. In applications where reliability and low error rates are critical (e.g., IoT, autonomous vehicles, and mission-critical systems), DF with best relay selection is the preferred choice. The best relay selection scheme significantly enhances the performance of cooperative communication systems, regardless of the protocol used. These insights contribute to the development of efficient, adaptive communication frameworks for future wireless networks, including 5G and beyond.

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